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CALCIUM—A FACTOR IN THE ECOLOGY OF TEAK (*TECTONA GRANDIS* LINN.)

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(Communicated by Dr. R. Misra)

Studies in the ecology of teak in M.P. have shown that the species is distributed over a wide variety of geological formations. These would include the Archians, Dharwars, Cretaceous traps, Intertrappean lime deposits, Lameta beds and soils derived from recent alluvium deposits. The distribution, however, is not continuous throughout the State. In the Satpura region teak forests are completely replaced by an evergreen forest. The Satpuras, at an altitude of over 3,000 feet, forms geo-morphological barriers. The change in the climate, conditioned by the increasing altitude, is not suitable for the species. At lower altitudes the discontinuity is due to purely edaphic factors. In most cases, the soils derived from Gondwana sandstones (found over the greater part of the Satpuras) are deficient in lime. This would explain why the species generally avoids these deposits.

The determination of exch. calcium of the teak soils collected from various teak forests of the State shows that a positive correlation can be obtained (Table I). Most soils with good teak growth register values above 0·3%. The species grows well on highly basic situations with exch. calcium exceeding 2–3%. The samples with exch. calcium exceeding 1% are fairly high. With the decrease in the calcium content of the teak

soils a corresponding deterioration in the teak growth sets in and the distribution of teak, over such areas, is seriously checked. On such situations teak is almost entirely absent or when present they have an extremely poor growth.

It is, therefore, evident that the distribution of teak in Madhya Pradesh follows lime-rich soils and the critical concentration below which teak will not grow is in the neighbourhood of 0·3% of exch. calcium. The distribution of this element in the profile fully substantiates this view (Table II). Good teak is usually encountered on soils with a calcareous subsoil. In strict contrast, poor teak is almost invariably found to be associated with acid conditions developing within the profile, which is generally due to the absence of lime.

TABLE I

Frequency of Teak Quality Classes and Regeneration with Exchangeable Calcium

Calcium range	0·1 0·2	0·2 0·3	0·3 0·4	0·4 0·5	0·5 0·6	0·6 0·7	0·7 0·8	0·8 0·8	0·9 above
1*	..	4	17	4	10	4	4	3	12
2	..	2	6	4	5	2	1	1	1
3	3	10	4	..	..	..	..	..	..
4	..	4	13	5	13	3	1	3	3
5	2	10	13	4	2	3	4	1	11

* = Growth and regeneration classes.
1 = First and second quality teak classes with good teak growth.
2 = Medium quality teak growth.
3 = Poor teak growth or teak entirely absent.
4 = Good regeneration of teak.
5 = Poor regeneration of teak.

Studies on the regeneration of the species in the forests of M.P. show that a correlation can be obtained only in the lower ranges of calcium (Table I). Good regeneration of the species is usually encountered in soils with exch. calcium between 0·3–0·4%. The results, however, tend to indicate that the regeneration is adversely affected on lime-rich soils (Table II). Such situations are found at West Kalibhet teak forests and the Ramna Forest Reserves at Sagar. In both these cases, it has been found that failure in natural regeneration is due to other factors that

tend to become critical. Some of these are dense shade, water-logging, heavy grazing and forest fires during the summer months.

TABLE II

Exchangeable Calcium Values and Their Frequency in the Soil Profiles for Growth and Regeneration Classes

Depth soil	1	2	3	4	5*
0″	0·54	0·53	0·31	0·50	0·52
6″	0·81	0·50	0·25	0·45	0·89
1′	0·84	0·55	0·26	0·47	1·30
2′	0·94	0·77	0·18	0·54	1·26
3′	1·55	..	..	1·14	1·77
4′	2·86	..	..	..	2·86

* Growth and regeneration classes.

The foregoing account of teak distribution clearly indicates positive correlation. Quite a number of workers are inclined to believe that this relation is solely due to the role of calcium as a 'soil improver' and may therefore not be taken up in appreciable amounts. On the other hand, Puri (1951) has indicated that calcium must be related to its present role as a nutrient and is involved in the metabolism of the species.

With a view to understand the role of calcium more intimately the following line of foliar diagnosis has been undertaken:

Studies on the Seasonal Uptake of Calcium

The data on seasonal variation of foliar calcium (Table III) shows that there is a gradual tendency for the percentage of calcium to increase (when results were expressed on dry weight basis) with the advance of the growing season. Towards leaf-fall values as high as 6% have been recorded. Puri and Prem Nath (in press) in their recent study of the soil climate of Dehra Dun have shown that the seasonal variation of foliar calcium can be correlated with the availability of the exch. calcium in the soils. Under monsoonic climate the amount of calcium found in the soil is lowest during the rains, when the leaching intensity is highest. During this period the uptake of the mineral is lowest. Subsequent rise in the soil calcium is accompanied by an increased uptake of the mineral. Although the paper is not available for a detailed study, nevertheless, it appears that

TABLE III

Seasonal Variation of Foliar Calcium in Teak

Date	Tree	Ash %	CaO %	Avg. ash %	Avg. CaO %	Remarks
15th July 1953	1 2 3	9·62 8·15 8·96	1·42 1·82 1·72	8·91	1·65	Approx. age of the trees are— 1 = 35 years, 2 = 32–35 years, 3 = above 75 years.
2nd Aug. 1953	1 2 3	10·69 9·18 10·54	2·21 2·13 2·62	10·14	2·32	
17th Aug. 1953	1 2 3	11·73 10·71 10·19	3·01 3·31 2·15	10·88	2·82	
5th Sept. 1953	1 2 3	12·80 13·68 10·40	3·67 2·89 2·78	12·29	3·11	
5th Oct. 1953	1 2 3	11·19 13·14 11·81	2·51 2·53 4·17	12·05	3·07	
5th Dec. 1953	1 2 3	15·68 16·65 14·54	3·18 3·25 4·06	15·62	3·50	
8th Jan. 1954	1 2 3	20·44 20·40 15·60	4·40 4·23 3·99	18·81	4·11	
4th Jan. 1954	1 2 3	27·32 23·47 14·00	6·03 5·16 3·40	21·60	4·86	Fallen leaves

variation in the mineral uptake cannot follow the lines indicated by them. Such variations have also been recorded by workers for the temperate regions where leaching intensity is more uniform. It would appear at the moment that, it is best to consider, the increase to be due to the accumulation of the element in the leaf in an insoluble form, rendering the element immobile with little chances of it being back transported.

Working on similar lines at Dehra Dun, Puri and Gupta (in press) have earlier reported a dissimilar trend. The uptake of the mineral after October is far below the quantity taken up at Sagar and towards leaf-fall the amount at Dehra Dun is about 2·75% while at Sagar it is about 5%.

The results of Puri and Gupta and those of the present investigation, therefore, shows a dissimilar concentration of the element in the leaves. Such variation in the results may be due to different climatic conditions under which teak grows. Besides, there are good indications to believe

that we are not dealing with a uniform teak population. The present investigation is, therefore, indicative of the fact that the nutritional balance of the forest trees is disturbed when introduced in areas outside the natural limits of the species or that we have distinct physiological races.

Evidences derived from the distribution of the species on calcareous situations and from the high concentration of foliar calcium (3–6%) give support to the fact that teak is a calciphyte. It grows well on highly basic situations and completes all phases of its normal life on it. It, therefore, becomes important that all forecasts of teak quality and growth should include, besides other factors, the calcium status of the forest soils.

Acknowledgment

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A STUDY OF THE VEGETATION AND CHOICE OF SPECIES IN THE AFFORESTATION OF RAJASTHAN

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(Communicated by R. Misra, F.N.A.SC.)

Introduction

The growing mass of sand in Rajputana and its slow and relentless march towards the north and north-east is one of the vital problems facing India at present. If the creeping of the desert resulting in devastation is allowed to continue the destruction would be practically complete before it will be realised and famine will not be an exception but the rule. It is true that in recent years the reclamation and afforestation of this desert tract is engaging the attention of both official and non-official organisations and thin fingers of irrigation and afforestation have been extended; but when compared with the general problem they are negligible. The chief problems in Rajputana are: (1) how to prevent more sand blowing into it from the west; (2) how to prevent movement of sand in and from the area so that fertile agricultural fields may not be covered with sand drifts; and (3) to see that the local population gets the requirements of timber and fuel. All these problems have been tackled by the *ad hoc* committee appointed by the Government of India. The chief solution to the problem lies in reclothing the entire area with plants and in protecting the existing vegetation. The afforestation may be a difficult feat. Yet it must be done as it alone can preserve the soil, increase humidity, retain moisture, and increase fertility. One big problem is what species to grow ? The aim should be not only to raise plants but plants of the greatest economic importance possible under the prevailing conditions, preferring plants of the locality that spread naturally. In the attached list plants naturalised to the prevailing conditions of Rajputana are given importance. Some of the exotic plants thriving well in the locality are also included. For the afforestation it is indispensable to know the nature of the existing vegetation in the locality and also the environment that governs plant growth.

Physiography

Rajputana covering an area of 1,30,900 square miles lies in the north-western part of India between 69·30′ and 78·17′ E. and 23·3′ and 30·12′ N. It forms the eastern extremity of the greatest desert areas of

the world extending from the west coast of Africa, including Sahara, part of Arabia, southern Persia, Baluchisthan, and part of Pakisthan. It is bordered by the desert areas of Bahawalpur and Sind in the west, Punjab in the north, and Uttar Pradesh and Madhya Bharat in the east. The southern boundary runs along the Rann of Cutch. The Aravalli ranges extending from Champaner in Gujarat in the south-west to near Delhi in the north-east extends over a length of about 430 miles. About three-fifths of Rajputana lies north-west of this line and about two-fifths on the south-east. The south-eastern part is comparatively fertile and contains hill ranges and forests. It supports some important rivers, the Chambal is the largest and has big tributaries like the Banas, Kalisind, and Parbathi.

The conditions in the north-western part are very different and it is this area which is dry and unproductive sandy waste. The desert characters are a little minimised because of rocky projections which raise their heads here and there. This desert tract covers an area of about 60,000 square miles and covers Jaisalmer, Bikaner, major portion of Jodhpur, and part of Jaipur. This area is dreary and desolate without rivers and good vegetation. The only river system that flows in this area is the Luni which arises from the Aravallis, south-west of Ajmer and flows west by south-west into the marshy Rann of Cutch. The important tributaries of this river are Lilri, Raipurluni, Guthiya, Sukri, Jawai, Jojri, and Bandi. None of them is perennial as they are purely rainfed streams.

Another noteworthy feature of Rajputana is the shallow expanse of the salt lake Sambar covering an area of about 100 square miles.

Development of Desert Conditions and Causes of Deterioration

Rajputana has a geological history of its own. According to Wadia (1949) and Krishnan (1952) the area was occupied by sea during the Jurassic, Cretaceous, and Eocene and that it must have been uplifted in the Tertiary. The Himalayas had come into existence by this time and some of the rivers emerging from it had an outlet for their waters into the Arabian Sea through Rajputana. During this time Rajputana must have experienced a humid climate and must have good forests. Recently Tertiary deposits of *Mesua ferrea* (Guttiferæ) have been reported by Lakhan Pal and Bose (1951) from Jodhpur. Since *Mesua ferrea* is a tropical tree which thrives well in moist warm and equitable climate with rainfall between 80″ to 200″ it has been pointed out by them that Rajputana must have satisfied all those conditions during the Tertiary period.

The desert conditions must have been brought about during and after Pleiocene when the monsoon became operative and probably after man

appeared [see Wadia (1949), Krishnan (1952)]. By the onset of drier conditions the rainfall became less and evaporation high with the result that desert conditions have been established. The encroachment of the desert on the existing river valleys has resulted in the drying up of Saraswathy; has shifted the course of Sutlej which had a parallel course with that of Indus, and Jumna which flowed out to the Arabian Sea before it was captured by the Ganges. Even though the deterioration of Rajputana may be primarily due to geological events it has also been accompanied by the work of man by destroying forests and by bad agricultural practices.

CLIMATE

One of the most characteristic features of Rajputana is the extreme variation of temperature. The winter of Rajputana is very cold at many places and the temperature falls below freezing point followed by frosty nights particularly in the north-western part. The cold season extends from the close of November to the middle of February. January is the coldest month. The summer starts by the end of March. During April, May and June heat is intense and scorching winds prevail with great violence. The mean maximum temperature in the hottest month May is 106° to 109° F. over most parts of Rajputana with the mean minimum at 75° to 80° F. In connection with the heat waves which generally occur throughout the area the temperature shoots up to a great extent and Shri Ganga Nagar has reported the maximum temperature giving a value of 122° F. Sand storms with great desiccating action are frequent and these bring a sudden fall in temperature giving a relief from the scorching heat.

By the onset of monsoon in July the weather cools down. The rainy season continues up to the middle of September. The average rainfall is 11″. Precipitation is also common during the winter months particularly in January.

The relative humidity of the atmosphere is low during major part of the year.

SOIL

According to Wadia, Krishnan, and Mukherjee (1935) the soil is derived from material formed by the disintegration of the local rock and partly from blown sand. But Viswanath and Ukil (1943) have classified the soil of Bikaner, Jaisalmer, and Jodhpur as coarse alluvium and the area comprising Jaipur, Ajmer, Marwara, and Udaipur as blown sandy soil.

The soil to the west of Aravallis are almost sandy, ill-watered and unproductive. Even in this region the area between the foot of the

Aravallis and the upper regions of Luni river is comparatively fertile. The second region lying to the south-east of Aravallis is fertile containing sandy loam and clay loam.

As western Rajputana is practically destitute of streams "desert" soil is met with. Because of the extremes of climate coupled with very little precipitation the soil particles are rapidly weathered down and they liberate injurious salts. These salts instead of being washed away to the sea accumulate in the soil making it unproductive and barren.

As water is scarce it has to be collected during monsoon for irrigation. Wherever possible artificial basins are constructed. In those areas where ground water is available it is utilised by digging deep wells.

Biotic Factors

The Rajputana desert is often called as a man-made desert. Man by felling trees and sometimes by scraping the ground vegetation has aided in the deterioration of the area.

The grazing cattle and sheep play an important part in the destruction of the vegetation. They browse on the shrubby plants and in their sweep across the ground they take grass, herbs, and tender seedlings of trees and shrubs without much discrimination. The effect of this on the vegetation is obvious. Also by the frequency of grazing plenty of wind erosion takes place as the surface soil gets loose due to their trampling.

Although the rodents are smaller than the principal livestock animals their numbers are enormous that they keep the vegetation in a depauperate condition.

Insect pests also make important contributions to the maintenance and spread of the desert. Of the several insects of the region the desert locust, *Schistocerca gregaria* Forsk., is the most important. Both the hopper and adult stages of this insect feed on all varieties of plants leaving only woody portions behind.

Vegetation

Paradoxical as it may sound the flora of Rajputana desert is not very poor. Excepting a small area and a few places here and there only a very few spots may be regarded as true desert in the strict sense.

The flora of Rajputana is very little understood. The first attempt was made by King (1879). Later Blatter and Hallberg (1918–21) studied the flora of Jodhpur, Phalodi, Bap and Jaisalmer. Recently Sarup (1951) published a list of common plants of Jodhpur. All the above records

mainly concern about the flora of western Rajputana. Excepting for three papers, Mulay and Ratnam (1950), Ramchandra (1950) and Ratnam (1951), no data is available as far as the vegetation of eastern Rajputana is concerned.

As the rainfall when compared with western Rajputana is high this area supports a good vegetation. The flora has a mingling of characters of peninsular and extra-peninsular regions. Tree species such as *Anogeisus latifolia*, *Boswellia serrata*, *Semicarpus anacardium*, *Ficus benghalensis*, *Spondias mangifera*, *Dendrocalamus strictus*, and *Bombax malabaricum* thrive well in this locality. Shrubs are more prominent than trees. Shrubby plants of the following genera are well represented: *Capparis*, *Cassia*, *Mallotus*, *Zizyphus*, *Helicteris*, *Hibiscus*, *Acacia*, *Gymnosporia*, and *Eugenia*.

The vegetation of western Rajputana is sparse. As the climate is hostile to plants only those with special xerophytic adaptation are able to establish. The bulk of the vegetation consists of stunted, thorny, or prickly shrubs and perennial herbs capable of drought resistance. Only a small number of trees such as *Prosopis spicigera*, *Salvodora persica*, *Tecoma undullata*, *Cordia rothi*, *Acacia arabica*, *Acacia leucophlœa*, and *Anogeisus pendula* grow in this locality. Hardly does any wild tree species reach a height of 15 to 20 feet.

The shrubby vegetation is mainly represented by *Acacia jacquemontii*, *Capparis aphylla*, *Capparis spinosa*, *Grewia populifolia*, *Cassia auriculata*, *Zizyphus* species, *Clerodendron phlœmoides*, *Tamarix articulata*, *Tamarix dioica*, *Calotropis procera*, *Balanites roxburghii*, and *Gymnosporia montana*.

The most important herbs are represented by species of *Polygala*, *Crotolaria*, *Tephrosia*, *Chenopodium*, *Abutilon*, *Citrullus*, *Justicia*, *Trianthema* and *Atriplex*.

The common grasses are *Cenchrus*, *Andropogon*, *Panicum*, *Eragrostis*, and *Aristida*.

The plants of this area may be grouped under two heads: those depending on rain-water—which appear above ground just after the rains and complete the life-cycle in an incredibly short time, dying out as soon as the soil gets dry or perennate by underground stems—and those depending on subsoil water. Plants depending on subsoil water generally possess a well-developed root system of extraordinary length when compared with the aerial portion and are capable of absorbing water from deep below. These plants show remarkable xerophytic adaptation.

As the edaphic factors vary from place to place the vegetation also shows remarkable changes and three main communities can be distinguished: psammophytic, lithophytic, and halophytic.

Psammophytic

Areas with sand dunes of the moving type.—Sand is piled up into dunes in a definite direction depending on the prevailing wind currents and the configuration of the place. Because of the action of wind the soil particles are sorted resulting in wind ripples which are of a forward motion generally south-west to north-east. As the sand is moving forward hardly any plant can obtain a footing. However a few seeds carried by wind may germinate when the monsoon begins. The early pioneers are *Calotropis procera* (c.), *Crotolaria burhia* (c.), *Aerua tomentosa* (c.), *Citrulus colocynthis* (f.), *Leptadænia spartium* (c.), *Indigofera argentea* (c.), *Farsetia jaquemontii* (o.), *Panicum turgidum* (f.), *Eleusine flagellifera* (o.), *Cyperus arenarium* (o.), and *Calligonum polygonoides* (o.).

Areas with more or less stable sand dunes.—This area is formed of loose sand which is not of the shifting type and carry trees on them. The vegetation consists of *Prosopis spicigera* (c.), *Tecoma undullata* (f.), *Acacia senegal* (f.), *Calotropis procera* (c.), *Leptadænia spartium* (c.), *Aerua tomentosa* (c.), *Citrulus colocynthis* (f.), *Panicum turgidum* (f.), *Eragrostis celiaris* (f.), *Cenchrus catharticus* (f.), *Pennisetum cenchroides* (o.), *Cyperus arenarium* (f.), *Calligonum polygonoides* (o.), and *Sacharum* species.

Areas with stabilised sand.—Due to prolonged weathering and by the accumulation and admixture of organic matter the sand has become stabilised. Wherever subsoil water is available cultivation is carried on. This area supports a fairly good vegetation. *Prosopis spicigera* (c.), *Acacia senegal* (f.), *Tecoma undullata* (c.), *Acacia arabica* (o.), *Salvodora persica* (c.), *Salvodora oleoides* (c.), *Capparis aphylla* (c.), *Acacia jacquemontii* (c.), *Acacia leucophlæa* (f.), *Balanites roxburghii* (c.), *Gymnosporia montana* (o.), *Calligonum polygonoides* (f.), *Aerua tomentosa* (c.), *Zizyphus rugosa* (f.), *Crotolaria burhia* (f.), *Calotropis procera* (c.), *Leptadenia spartium* (f.), *Clerodendron phlœmoides* (c.), *Cassia occidentalis* (c.), *Tephrosea purpurea* (c.), *Indigofera argentea* (f.), *Cenchrus catharticus* (c.), *Eragrostis celiaris* (c.), *Panicum antidotale* (f.), *Pennisetum cenchroides* (f.), *Boerhavia diffusa* (f.), and *Tribulus terrestris* (f.) are the chief species. Also exotic plants such as *Albizzia lebbeck*, *Prosopis juliflora*, *Melia azedarach*, *Azadirachta indica*, and *Ficus religiosa* thrive well.

(c.) common; (f.) frequent; (o.) occasional.

Lithophytic

The rocky region of western Rajputana comprises three main areas:

(*a*) Kailana–Jodhpur–Mandor Plateau,

(*b*) Jaisalmer Plateau, and

(*c*) Barmer Hills.

Euphorbia nerifolia (c.), *Monsonia* sp. (c.), *Acacia senegal* (c.), *Indigofera cordifolia* (c.), *Orygia decumbens* (f.), *Mimosa hamata* (f.), *Capparis spinosa* (f.), *Barleria acanthoides* (f.), *Grewia populifolia* (f.), *Gracilia royleana* (o.), *Fagonia cretica* (o.), *Eleusine aegyptiaca* (f.), *Aristida histicula* (f.) are found.

Halophytic

Sambar salt lake and its neighbouring areas constitute a large saline tract of the desert. Though water is available in the soil plants are unable to utilise it because of the high concentration of the salt dissolved in it. Very few plants grow in this locality. *Tamarix dioica* (c.), *Haloxylon salicornicum* (f.), *Sueda fructicosa* (c.), and *Atriplex cressifolia* (o.) are the chief plants of the locality.

CHOICE OF SPECIES

Acacia arabica (Leguminosæ).—A very important tree of the desert, grows well on stabilised soil, bark used as tanning material, gum a substitute for gum arabic, leaves and pods as fodder for cattle, wood as good timber and fuel.

Acacia jacquemontii (Leguminosæ).—A thorny shrub of the desert found frequently in dry loose sand, good sand binder, gum valuable, bark used for tanning, leaves as fodder, wood as excellent fuel.

Acacia senegal (Leguminosæ).—A small tree of the rocky areas and plains. This plant is very important as it thrives well in poor soil. It has been tried with success in Jaipur on shifting sand. The plant is remarkable for its capacity to resist drought and adverse conditions; gives gum arabic, leaves as fodder and wood as fuel.

Acacia catechu (Leguminosæ).—A thorny tree of the desert found frequently in shallow and stony soil. It is capable of surviving under adverse conditions; yields good gum, timber useful for construction purposes and fuel.

Acacia leucophlœa (Leguminosæ).—A thorny tree of the plains. Thrives well in sandy areas,

Aerua tomentosa (Amarantaceæ).—A characteristic undershrub of the desert, rapidly spreading and a good sand binder.

Agave americana (Amaryllidaceæ).—A shrubby plant naturalised in many parts of Rajputana. Valuable for checking the movement of sand and surface soil. It can grow well under great variations of temperature. It is also remarkable for its capacity to grow in poor soil where anything else will not grow.

Alhagi maurorum (Leguminosæ).—A spiny shrub of the desert, grows on loose sand. A good sand binder.

Albizzia lebbeck (Leguminosæ).—A moderately sized tree that flourishes on any soil. This rapidly growing exotic tree has been tried in many parts of the desert with great success. It is well suited for places where sand drifts occur.

Anogeisus pendula (Combretaceæ).—A small tree found in the plains. Easily propagated by root suckers. Wood very hard, leaves as fodder for camels.

Andropogon foveolatus (Graminæ).—A densely tufted grass found in all parts of the desert. A good sand binder.

Aristida dipressa (Graminæ).—Grows well in dry barren soil. A good sand binder.

Azadirachta indica (Meliaceæ).—This rapidly growing tree flourishes better than most other plants in soil with a waterless subsoil and has been tried with encouraging results in most parts of Rajputana. Seeds medicinal.

Balanites roxburghii (Simarubaceæ).—A thorny shrub of the plains. A good sand binder. Seeds yield an oil.

Calligonum polygonoides (Polygonaceæ).—A slow growing shrub of the desert common on loose sand and has remarkable ability of adaptation to diverse circumstances. When growing on sand dunes it prefers the very crest of it. A very good sand binder.

Calotropis gigantea (Asclepiadaceæ).—A large shrub common in the plains even on loose sand. It is best suited to survive in the desert being rapidly growing, able to grow on pure sand and quite indifferent to habitat; a good sand binder; yields a fibre.

Calotropis procera.—As above.

Capparis aphylla (Capparidæ).—A common spiny shrub of the desert. It is a good sand binder and is well adapted for the conditions.

Capparis spinosa (Capparidæ).—A small tree of the plains, rocky areas and pure sand. Useful as a sand binder and for covering rocky areas.

Cassia auriculata (Leguminosæ).—A shrub successfully cultivated as a hedge in many parts of the area. Grows well on pure sandy soil. A good sand binder; for clothing dry and rocky areas.

Cassia sophera (Leguminosæ).—A rapidly growing shrub, a good sand binder; for hedge.

Cenchrus biflorus (Graminæ).—An erect grass of the desert, a good sand binder.

Cenchrus catharticus.—As above.

Citrulus colocynthis (Cucurbitaceæ).—A prostrate herb common on sandy soil. It is a very remarkable plant of the desert which remain green throughout the year in spite of its long trailing branches. The possession of long, slender, woody tap root system enables the plant to dispense with all xerophilous characteristics. A good sand binder. This with *Ipomea biloba* prevents sand drifts. Fruit medicinal.

Chloris barbata (Graminæ).—A perennial tufted grass of the desert found frequently in sandy regions. A good sand binder. A good fodder when young.

Clerodendron inerme (Verbinaceæ).—An evergreen quick growing and drought-resistant shrub. A good sand binder.

Clerodendron phlœmoides (Verbinaceæ).—A shrub of rocky areas and stabilised soil. Useful for hilly tracts.

Commiphora mukul (Burseraceæ).—A quick growing small tree of the rocky areas; can be propagated by cuttings; gives gum Indian Bdellium.

Cordia rothi (Boraginaceæ).—A small tree planted and self-sown in various parts of Rajputana; a good tree for irrigated areas.

Crotolaria burhia (Leguminosæ).—A low undershrub, one of the early colonisers in fresh sand; a good sand binder; spreads rapidly.

Cyamopsis psoralioides (Leguminosæ).—A robust erect annual found cultivated and also as an escape. A good fodder crop for irrigated areas; pods for human consumption.

Cynodon dactylon (Graminæ).—A perennial grass with creeping stems and branches. A good sand binder, prevents erosion very well. One of the pioneer grasses on the sand dunes.

Cyperus arenarius (Cyperaceæ).—A sedge capable of withstanding adverse conditions, a pioneer species in fresh sand, good sand binder.

Dalbergia sisso (Leguminosæ).—A large tree successfully cultivated in many parts; trunk gives one of the finest timbers; will thrive well in irrigated areas.

Dianthium annulatum (Graminæ).—A densely tufted grass of the desert; very good sand binder and fodder.

Dianthium caricosum.—As above.

Dodonæa viscosa (Sapindaceæ).—An evergreen shrub used as hedge in many places (Jaipur, etc.); good for covering dry and bare slopes.

Eleusine flagellifera (Graminæ).—A parennial creeping grass of the sandy areas, very good sand binder.

Euphorbia nerifolia (Euphorbiaceæ).—Good for sandy and hilly areas.

Fagonia cretica (Zygophyllaceæ).—A spreading spiny herb of sandy areas; prevents erosion very well because of the spreading branches.

Farsetia hamiltonii (Cruciferæ).—A pioneer species on loose sand; a good sand binder.

Grewia populifolia (Tiliaceæ).—A small shrub common in rocky areas. Very good for hilly and rocky places.

Gymnosporia montana (Celastraceæ).—A small spinescent tree well adapted for the desert conditions and will thrive well on any soil.

Gynandropsis pentaphylla (Capparidæ).—A good sand binder.

Haloxylon salicornicum (Chenopodiaceæ).—A common plant of the saline areas; good for plantations in saline tract and on the banks of saline depressions.

Hibiscus micranthus (Malvaceæ).—A shrubby plant of rocky areas, good for hilly regions.

Indigofera argentea (Leguminosæ).—A prostrate herb, one of the pioneer plants on sand dunes. It owes its peculiar fitness as a sand plant to its mode of growth. The thick woody stem protrudes a few inches above the ground and supports a crown of twiggy branches spreading out horizontally. The plants if grown close the flat crowns form a layer preventing the wind from reaching the soil and stirring it up.

Indigofera cordifolia (Leguminosæ).—As above.

Ipomea biloba (Convolvulaceæ).—This plant with *Citrulus colocynthis* preve nts wind erosion very well.

Lowsonia alba (Lythraceæ).—A bush good for irrigated areas as a hedge.

Melia azedarach (Meliaceæ).—A tree successfully cultivated in many parts of the desert. A good tree for irrigated areas.

Panicum turgidum (Graminæ).—A grass of the sand dunes; good for fixing sand against erosion.

Parkinsonia aculeata (Leguminosæ).—A rapidly growing exotic plant introduced in many parts of Rajputana; a good sand binder and hedge.

Prosopis juliflora (Leguminosæ).—A small evergreen tree recently introduced in many parts of Rajputana. This plant is drought resistant and rapidly growing; will grow on any barren ground where few other plants will grow; very good for irrigated areas.

Prosopis spicigera (Leguminosæ).—An important tree of the desert; very drought resistant and prevents sand drifts; leaves as fodder, pods for human consumption, wood for fuel and implements.

Ricinus communis (Euphorbiaceæ).—A cultivated shrub often found running wild in the plains; good for sandy areas; seeds yield oil.

Saccharum celiare (Graminæ).—A perennial grass of considerable importance because of its capacity to fix moving sand. This xerophytic grass will grow well in any loose soil; one of the pioneers to colonise sand dunes.

Saccharum munja (Graminæ).—A tall tufted grass of the desert, grows even on very dry soil; a good sand binder. It has been tried with success in Jaipur on shifting sand dunes; used for thatching and making baskets.

Salvodora oleoides (Salvodoraceæ).—An evergreen tree of the desert, drought resistant, good for sandy areas; timber good, leaves as fodder.

Salvodora persica.—As above.

Sophera griffithii (Leguminosæ).—A good hedge plant.

Sporobolus orientalis.—A grass good for saline areas; good sand binder; fodder when young.

Tamarix articulata (Tamarscinæ).—An important tree of the desert. It shows important adaptations for a xerophytic climate; for sandy areas.

Tamarix dioica (Tamarscinæ).—A gregarious tree found frequently in saline areas; good for plantations on banks of saline depressions.

Tecoma undulata (Bignoniaceæ).—An indigenous tree of the desert; good for sandy areas; wood useful.

Tephrosea purpurea (Leguminosæ).—A hairy shrub of stabilised soil; a good sand binder; very good for manure.

Tribulus terrestris (Zygophyllaceæ).—A spreading herb common in all parts of the desert. Because of the horizontally spreading branches erosion is prevented.

Trianthema pentandra (Ficoidæ).—A spreading herb of the sandy areas. This plant with *Indigofera argentea* prevents erosion of sand very well.

Trianthema crystallina (Ficoidæ).—As above.

Withania somnifera (Solanaceæ).—A small shrub of the desert; good sand binder; medicinal.

Zizyphus jujuba (Rhamnaceæ).—A thorny shrub characteristic of the desert, in sandy soil. Cultivated in many parts for its fruits. Good for irrigated sandy places. Wood for fuel, leaves lopped for fodder.

Zizyphus rugosa (Rhamnaceæ).—A shrub of sandy areas. It will grow in any soil, spreads rapidly, and binds sand. Leaves as fodder.

Zizyphus numularia.—As above.

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CYTOLOGY OF MILLETS

I. Genus *Eleusine*

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Millets have not been dealt with in detail cytologically. This work was thus taken up to study some species of this genus and to verify earlier reports on secondary associations by Krishnaswamy (1939) with the help of an abundant data. The original samples of *E. coracana* were obtained from three different sources: (1) District Garhwal, (2) District Almora and (3) Local variety of Allahabad District. The other species, *viz.*, *E. indica* and *E. verticillata*, were collected from local fields. A fourth species, *Dactyloctinium ægepticum*, which was previously included in this genus and now given a separate name, has also been included in this study.

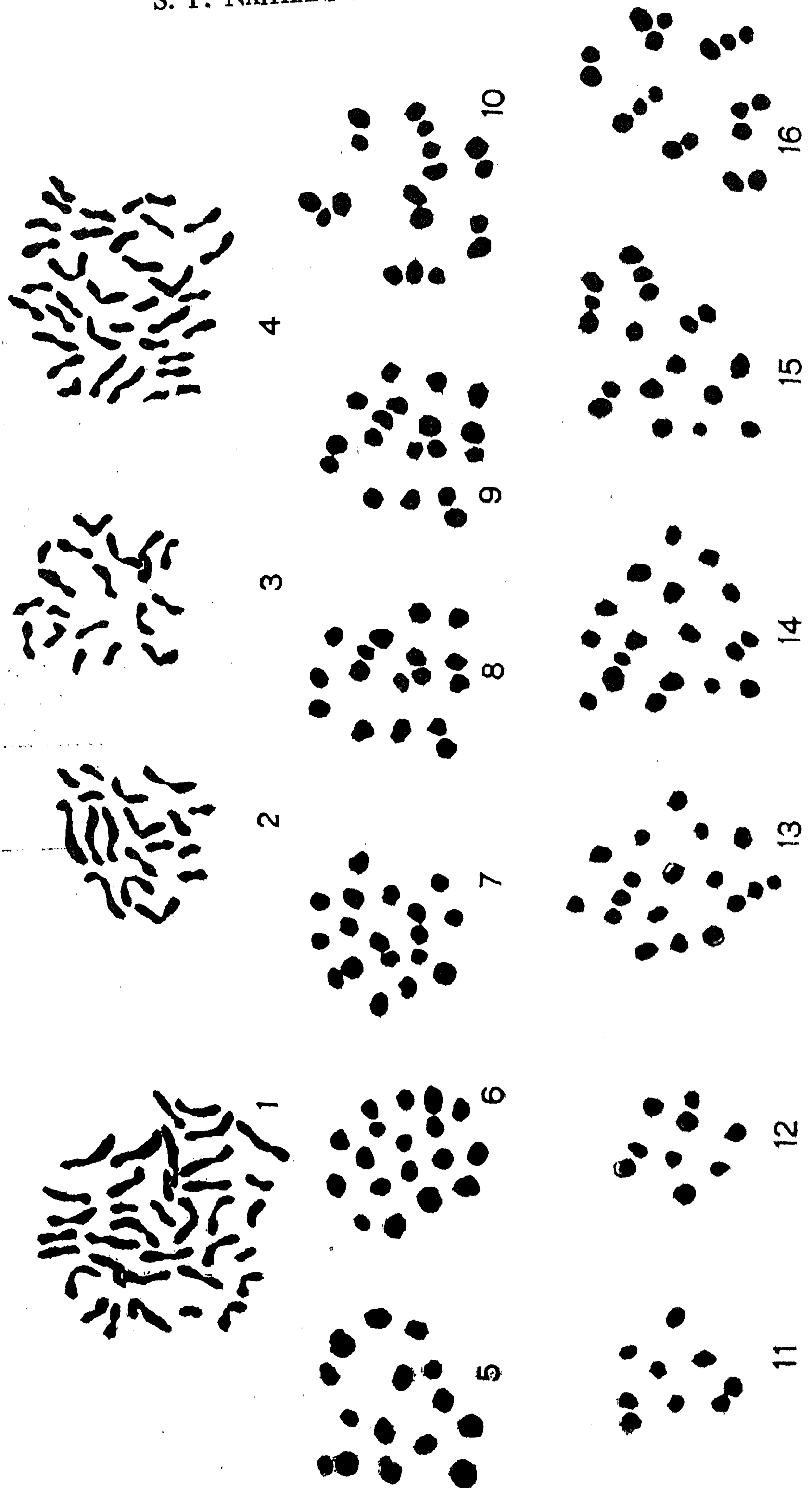
Root tips and flower buds were fixed in La Cour's 2 BE (1931). McClintock's smear method (1929) was also used for the meiotic studies.

Chromosome numbers of species of *Eleusine* and *Dactyloctinium* are given in Table I.

Table I

Name of plant	Somatic numbers	No. of bivalents at meiosis
E. coracana	36	18
E. indica	18	9
E. verticillata	18	9
Dactyloctinium ægepticum	36	18

Somatic chromosomes of six varieties (T 134, T 149, T 41, T 63, T 121 and T 313) from Tarikhet, Almora and two other varieties, one from district Garhwal and the other local one were examined. All of them at metaphase showed the somatic number to be $2n$–36 (Fig. 1). Chromosome number of *E. verticillata* has been determined for the first time and is $2n$–18 (Fig. 2). *E. indica* also showed $2n$–18 (Fig. 3). Somatic number for *Dactyloctinium ægepticum* was found to be $2n$–36 (Fig. 4).



FIGS. 1–16

In meiosis of pollen mother cells of these species the nuclear membrane disappeared at the inception of prometaphase and a spindle began to be organised. At the end of diakinesis the converging movement of bivalents became more intense resulting in crowding of chromosome pairs in the centre of the nucleus. The bivalents were quite free from each other without any physical connection.

At this stage the secondary association of chromosomes began which manifested itself in a prominent manner in the succeeding metaphase and anaphases (Figs. 5–16). Secondary association may be described as pairing at metaphase resulting from a generalized attraction between bivalents related phylogenetically though distantly. It is a characteristic of polyploid chromosomes and is a measure of quantitative and structural changes in a given complement.

The various groupings of secondary associations observed in polar views (some of these also confirmed in equatorial views) of Metaphase I in the genera *Eleusine* and *Dactyloctinium* are given in Table II.

TABLE II

Types of Secondary Associations Observed at Metaphases I and II

Name of plant	No. of secondary associations	No. of bivalents in association 1	2	3	4	No. of cases observed
E. coracana	1	15	..	1	..	5
	2	14	2	..	..	13
	3	11	2	1	..	10
	4	8	2	2	..	9
	5	6	3	2	..	7
	7	..	4	2	1	3
E. indica	1	7	1	..	..	8
	2	5	2	..	..	6
E. verticillata	1	7	1	..	..	5
	2	5	2	..	..	5
D. ægepticum	2	12	..	2	..	3
	3	11	2	1	..	6
	4	8	2	2	..	10
	7	..	3	4	..	4

From Table II it is evident that maximum grouping in *E. coracana* consists in one group of four bivalents, two groups of three bivalents each and four groups of two bivalents each. Krishnaswamy (1939) has, however, recorded only a maximum association of two groups in any one group and thus his basic number for *E. coracana* comes to nine. But by our studies there is a variation in groupings as well as in basic number that being seven and not nine. *E. verticillata* and *E. indica* both have a maximum grouping in two groups of two bivalents each and five free bivalents. *D. ægepticum* has maximum grouping formed by association of three bivalents in each of the four groups and two bivalents in each of the three groups. Thus in all these species the basic number is seven.

DISCUSSION

Secondary Association of Chromosomes

The association of bivalents at meiosis was first observed by Kuwada (1910) in *Oryza sativa* only in second metaphase. Ishikawa (1911) found secondary pairing also at first metaphase of *Dahlia variabilis*. Since then various authors have found the phenomenon in different genera. Darlington (1928) originally advocated the theory of secondary pairing in his studies on *Prunus*. It was put on a systematic basis by Lawrence (1931) who has discussed all the then known cases of secondary pairing. Heilborne (1937) also discussed this phenomenon and considered that such associations are purely mechanical in origin. According to him chromosomes of equal sizes are associated irrespective of homology. In genera *Eleusine, Dactyloctenium, Setaria* and *Pennisetum* (the last two genera not included in this paper), however, it was observed that the secondarily paired chromosomes were not identical in size in all cases. Alam (1936) in *Brassica*, Riccharia (1937) also in *Brassica* and Iyenger (1939) in *Cicer* have also recorded secondary associations between short and long bivalents.

Thomas and Revell (1946) in *Cicer arietinum* have shown that in diploid analysis of secondary association need not indicate chromosome relationship, whereas in tetraploids it may do so depending on the degree of prezygotene orientation and the amount and distribution of heterochromatin. Led by this idea they have shown interbivalent connections which are supposed to be due to persisting heterochromatin material of the chromosomes. Our observations lead us to conclude that the fusion between heterochromatic regions at pachytene is not responsible for the characteristic secondary pairing at metaphase. Observations on *Eleusine* and *Dactyloctinium* revealed no such connections at diakinesis and stages onwards.

Thus by studying the secondary pairing at metaphases I and II in genera *Eleusine* and *Dactyloctinium* assuming that structural changes have occurred, the haploid genoms can be represented as follows:

E. coracana	*E. indica*	*E. verticillata*	*D. ægepticum*
AAAA	AA	AA_1	AA_2A
BBB	BB	BB_1	BB_2B
CCC	C	C_1	CC_2C
DD	D	D_1	DD_2D
EE	E	F_1	EE_2
FF	G	G_1	FF_2
GG	..	..	GG_2

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EXPLANATION OF FIGURES

FIG. 1. Somatic chromosomes of *Eleusine coracana* (2*n*-36).

FIG. 2. Somatic chromosomes of *E. indica* (2*n*–18).

FIG. 3. Somatic chromosomes of *E. verticillata* (2*n*–18).

FIG. 4. Somatic chromosomes of *Dactyloctinium ægepticum* (2*n*–36).

FIGS. 5 to 10. Polar views of Metaphase I in *E. coracana* showing secondary associations. FIG. 5. 15–1 (3); Fig. 6. 14–2 (2); Fig. 7. 11–1 (3)–2 (2); Fig. 8. 8–2 (3)–2 (2); Fig. 9. 6–3 (2) -2 (3); Fig. 10. 1 (4)–2 (3)–4 (2).

FIG. 11. Polar view of Metaphase I in *E. indica* showing an association of 2 (2)–5.

FIG. 12. Polar view of Metaphase I in *E. verticillata* showing an association of 2 (2)–5.

FIGS 13–16. Polar views of Metaphase I in *Dactyloctinium ægepticum* showing secondary associations. Fig. 13. 12–(2 (3); Fig. 14. 11–1 (3)–2 (2); Fig. 15. 8-2 (3)–2 (2); Fig. 16. 4 (3)–3 (2).

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